

Proposed abstract for a poster presentation at GIS 2002:

Spatial Metadata for Global Change Investigations Using Remote Sensing

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Satellite and aircraft-borne remote sensors have gathered petabytes of data over the past 30+ years. These images are an important resource for establishing cause and effect relationships between human-induced land cover changes and alterations in climate and other biophysical patterns at local to global scales. However, the spatial, temporal, and spectral characteristics of these datasets vary, thus complicating long-term studies involving several types of imagery. As the geographical and temporal coverage, the spectral and spatial resolution, and the number of individual sensors increase, the sheer volume and complexity of available data sets will complicate management and use of the rapidly growing archive of earth imagery. Mining this vast data resource for images that

provide the necessary information for climate change studies becomes more difficult as more sensors are launched and more imagery is obtained.

The long-term goal of this research is to improve global change studies by facilitating access to and improving analysis of remote sensing imagery. This goal requires the development and testing of techniques for characterizing the spatial complexity and content of images stored in the rapidly growing archives of satellite and aircraft data. Ultimately, these spatial indices could be used to reflect the underlying landscape patterns and processes, identify the "characteristic" scale or optimal scale of analysis, and provide guidance on the optimum resolution needed to accurately depict natural and anthropogenic alterations to the earth's surface without introducing extraneous noise or needless detail. Achieving this goal will require the implementation of open, distributed, and responsive data system architectures to enable the productive use of space- and airborne imagery in the public and private sectors.

Even seemingly simple searches for satellite images depicting a particular location involve time-consuming analyses of the many individual scenes that have been gathered over the past 30 or more years, each having different sensor platforms, levels of quality (due to cloud cover, illumination, etc.), dates, and types of pre-processing. Metadata schemes such as the Earth Observing System Data and Information System (EOSDIS) Core Metadata Model address this to some extent by specifying location, lineage (including image processing and projection information), sensor characteristics, and other identifying characteristics to aid searches for images of specific areas at specific times. These "high-level descriptors" are generated when raw imagery is prepared for release. Mid-level descriptors include rule-based semantic identification of

recognizable objects, such as lakes, mountains, and vegetated areas that occur within a scene. Low-level descriptors are image characteristics such as shape, color, pattern, and texture. By their nature, the mid- and low-level descriptors are often user-specific, and it would not be practical to add all of this information as formal metadata, since it is impossible to anticipate all uses to which an image may be applied.

It is becoming apparent that the common practice of using general metadata structures to access specific images is ineffective, thus pointing toward a need for intelligent image query techniques. Given the difficulties of indexing and searching the content of images stored in data repositories, we propose a hierarchical approach that begins with the traditional high-level metadata items (such as location, date, sensor, etc), proceeds through customized mid-level searches of object identification (which would include items such as cloud cover) and contextural relationships, eventually followed by identification of images that characterize the often small objects or subtle differences that are of interest in global change studies. The latter requires low-level descriptors that use geometric characteristics (such as size, shape, and orientation), radiometric characteristics or spectral signatures, and measures of texture and pattern to identify regions of interest to the user. Imagery selected by higher-level searches will be characterized and the results will be presented to the user as a plot of changes in fractal dimension, lacunarity, and spatial autocorrelation with changes in resolution. These plots will enable the user to identify whole scene breakpoints at which resampling to coarser resolutions will change the spatial structure of the image and possibly obscure the phenomenon of interest.

Since the multi-spectral nature of most remotely sensed imagery has engendered an extensive list of tools for conducting radiometric investigations of images, we focus in

this project on developing and evaluating indices of the spatial characteristics of either whole images in a global context or local subsets of images in the form of fixed or moving windows. Using ICAMS, the Image Characterization And Modeling System, this work evaluates the performance of several measures of spatial complexity as content-based, low-level descriptors to select individual images from a database that meet user-specified criteria for these low-level descriptors. ICAMS is a Java-based application that was developed by the authors to provide global (whole-image) and local measurements of fractal dimension, lacunarity, and Moran's I and Geary's C spatial autocorrelation indices.

Atlanta, Georgia's four-fold increase in population from 1970 to 2000 provides a case study for evaluating the performance of these content-based indices of image complexity. Preliminary results using Landsat Multispectral Scanner, Thematic Mapper, and Enhanced Thematic Mapper data along with Ikonos commercial imagery and digital orthophotoquads show that Moran's I and Geary's C indices of spatial autocorrelation are useful tools for identifying areas of the city and its periphery that have undergone significant landcover changes. Fractal dimension measured by the walking-divider method provides noisier results with less correlation to changes in population density, housing starts, and other indicators of urbanization. Plots of changes in these indices of spatial complexity versus changes in pixel size (through resampling of imagery and through different sensors) show inflection points that provide some indication of the resolution at which particular processes (such as new housing development in a previously forested area) are no longer visible.